Meat Science 93 (2013) 572–578

Contents lists available at SciVerse ScienceDirect

Meat Science

journal homepage: www.elsevier.com/locate/meatsci

Effect of different temperature–time combinations on physicochemical, microbiological, textural and structural features of sous-vide cooked lamb loins

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ARTICLE INFO

Article history:
Received 24 March 2012
Received in revised form 29 June 2012
Accepted 10 November 2012

Keywords:
Lamb
Sous-vide
Color
Instrumental texture
Microstructure
Cryo-SEM

ABSTRACT

Lamb loins were subjected to sous-vide cooking at different combinations of temperature (60, 70, and 80 °C) and time (6, 12, and 24 h). Different physicochemical, histological and structural parameters were studied. Increasing cooking temperatures led to higher weight losses and lower moisture contents, whereas the effect of cooking time on these variables was limited. Samples cooked at 60 °C showed the highest lightness and redness, while increasing cooking temperature and cooking time produced higher yellowness values. Most textural variables in a texture profile analysis showed a marked interaction between cooking temperature and time. Samples cooked for 24 h showed significantly lower values for most of the studied textural parameters for all the temperatures considered. Connective tissue granulation at 60 °C and gelation at 70 °C were observed in the SEM micrographs. The sous-vide cooking of lamb loins dramatically reduced microbial population even with the less intense heat treatment studied (60 °C–6 h).

1. Introduction

Sous-vide cooking can be defined as the cooking of raw materials under controlled conditions of temperature and time, inside heat-stable vacuumized pouches or containers followed by rapid cooling (Baldwin, 2012; García-Segovia, Andrés-Bello, & Martínez-Monzo, 2007). This technique is nowadays used in restaurants, catering and industrial processing because of its ease and appropriateness for the management of prepared foodstuff, providing the manipulation of the already cooked food after the thermal treatment with no risk of microbial contamination, and thus, increasing food shelf-life (Armstrong, 2000). The sous-vide cooking conditions suggested by chefs for different types of meat are very different to those used for traditional cooking methods or in catering. Thus, commonly recommended combinations of temperature and time by chefs for beef, pork or lamb are around 58–63 °C for 10–48 h (Myhrvold, Young, & Bilet, 2011) while temperatures for pork in catering most likely reaches 75–80 °C (Armstrong, 2000).

Both, temperature and cooking time have a large effect on the eating quality of meat (Christensen, Ertbjerg, Aaslyng, & Christensen, 2011). As a consequence of heating, several changes take place in meat, such as protein denaturation, fiber shrinkage or collagen solubilization (Tornberg, 2005). While the latter has a tenderizing effect, most changes affecting the myofibrillar proteins during cooking cause an increase in toughening (Laakkonen, Wellington, & Sherbon, 1970; Nikmaram, Yarmand, Emamjomeh, & Darehabi, 2011).

There is only limited information about the effect of low temperature–long time (LT–LT) combinations on the characteristics of sous-vide cooked meats It seems that under these conditions, there occurs an intense collagen solubilization, which in turn leads to a great formation of gelatin, while the myofibrillar based toughening is still not very intense (Sánchez del Pulgar, Gázquez, & Ruiz-Carrascal, 2012). Other authors have reported the effect of such LT–LT sous-vide cooking treatments on instrumental color, water losses, moisture content, and instrumental texture of microbial counts of different meats (Christensen et al., 2011; Díaz, Nieto, Garrido, & Bañón, 2008; García-Segovia et al., 2007; Hansen, Knøchel, Juncher, & Bertelsen, 1995). However, despite the fact that lamb meat is frequently sous-vide cooked at this LT–LT conditions in many restaurants and catering (Myhrvold et al., 2011), as far as our knowledge, there is not scientific information available for sous-vide cooked lamb meat. On the other hand, the lamb meat sector has traditionally been a mainstay of the economy of several regions in Spain. However, in the last 10–20 years, there has been a decrease in the per capita consumption of lamb meat, due to several factors, one of them being the long time that preparation and cooking of traditional lamb recipes involve. The production of sous-vide, ready to eat, lamb meat based dishes could be an interesting alternative for the commercialization of this livestock.

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http://dx.doi.org/10.1016/j.meatsci.2012.11.014

On the other hand, the use of such cooking temperatures might not be enough for destruction of some spore-forming pathogenic bacteria and other spoilage microorganisms, like lactic acid bacteria (Díaz, Garrido, & Bañón, 2010; Vaudagna et al., 2002). However, there is not much scientific information about the effect of these temperatures for such long cooking times on counts for different microbial groups.

Thus, this research was aimed to study the effect of sous-vide cooking of lamb loins at different temperature–time combinations on different physico-chemical, textural, microbiological and structural features.

2. Materials and methods

2.1. Experimental design

Lamb loins sous-vide cooked at different temperature–time combinations were studied. The *Longissimus dorsi* muscle was chosen because it is a top quality primal that is frequently sous-vide cooked both in restaurants and in the catering industry.

Nine different combinations of time (6, 12 and 24 h) and temperature (60, 70 and 80 °C) were used for cooking 45 lamb loins (n = 5 for each batch). In addition, 5 lamb loins were used for performing analyses of fresh meat. All loins were from a homogeneous production batch of lamb averaging 26 kg live weight and 90 days of age.

Samples were weighed, packaged in vacuum plastic bag (nylon/polyethylene pouches; heat resistance of −40 °C/+120 °C, O_2 permeability of 9 cm^3/m^2 per 24 h at 4 °C/80% HR and water steam permeability of 1.2 g/m^2 per 24 h) (Joelplas SL, Barcelona, Spain) and cooked in thermostatized water baths at different temperature–time combinations. The internal temperature was monitored using a data logger Testo735-2 (Testo, Lenzkirch, Germany) equipped with a needle thermocouple. Once the cooking process had finished, the pouches were removed from the water bath and submerged in iced cold water (2 °C) for 1 h. Subsequently, the packaged loins were kept under refrigeration (2 °C) overnight.

The day after the cooking process, weight, moisture content, instrumental color, and instrumental texture features were measured. In addition, samples for microbiology and microscopy were taken. The rest of the sample was kept at −80 °C until analysis.

2.2. Moisture content and water losses

Cooking losses were calculated by difference of weight before and after cooking and moisture content was determined by drying the samples (5 g) at 102 °C (A.O.A.C., 2000).

2.3. Instrumental color measurement

Color was measured across the cut surface of the cooked loin after chilling. L* value (lightness), a* value (redness) and b* value (yellowness) were obtained using a Minolta Colorimeter CR-300 (Minolta Camera Co., Osaka, Japan) programmed to used the built-in internal illuminant D65. Means of readings on three locations on each sample were determined. Before each series of measurements, the instrument was calibrated using a white ceramic tile.

2.4. Instrumental texture analyses

Texture analyses were performed in a texturometer TA XT-2i Texture Analyser (Stable Micro Systems Ltd., Surrey, UK). For the determination of the texture profile analysis (TPA), uniform portions of the cooked loins were cut into 1 cm^3 cubes. For each sample, eight cubes were obtained and analyzed. They were axially compressed to 50% of the original height with a flat plunger of 50 mm in diameter (P/50) at a crosshead speed of 2 $mm \cdot s^{-1}$ through a 2-cycle sequence. The following texture parameters were measured from force deformation curves (Bourne, 1978): Hardness (N) = maximum force required to compress the sample (peak force during the first compression cycle); Adhesiveness (N·s) = work necessary to pull the compressing plunger away from the sample; Springiness (cm) = height that the sample recovers during the time that elapses between the end of the first compression and the start of the second; Cohesiveness (dimensionless) = extent to which the sample could be deformed before rupture (A1/A2, A1 being the total energy required to for the first compression and A2 the total energy required for the second compression); and Chewiness (N·cm) = the work needed to chew a solid sample to a steady state of swallowing (hardness × cohesiveness × springiness).

Shear force analysis on cooked samples was performed using a Warner–Bratzler blade (3 × 1 × 1 cm), which sheared the specimen perpendicularly to the muscle fibers at a constant speed of 1 $mm \cdot s^{-1}$ and then pushed through the slot. The maximum force (N) required to shear the sample was measured. Six determinations were performed for each cooked sample.

2.5. Microbiology

In order to carry out the counts, 10 g of the sample of the loins were homogenized in 90 ml sterile 0.1% peptone in a Stomacher (Lab Blender, Model 4001, Seward Medical, London, UK) for 30 s. Appropriate dilutions were made with 0.1% peptone broth and 1 ml was plated onto the culture media under the following conditions. Total mesophilic and psychrotrophic counts on Plate Count Agar (PCA, Oxoid, Unipath, Basingstoke, UK) for 72 h at 30 °C and 7 days at 7 °C, respectively; *Enterobacteriaceae* on Violet Red Bile Glucose Agar (VRBG, Oxoid) for 24 h at 37 °C; Coliforms on Violet Red Bile Agar (VRBA, Oxoid) for 24 h at 37 °C; lactic acid bacteria, LAB, on MRS Agar (Oxoid) in anaerobic conditions for 72 h at 30 °C; Gram-positive Catalase-positive cocci on Mannitol Salt Agar (MSA, Oxoid) after 72 h at 37 °C; sulfite reducing clostridia on Sulfite-Polymyxin-Sulfadiazine (SPS) agar incubated anaerobically for 72 h at 37 °C; intestinal enterococci on Slanetz and Bartley agar (S&B, Oxoid) for 24 h at 37 °C; and *Brochothrix thermosphacta* on Streptomycin Thallous acetate actidione agar (STAA, Oxoid) for 72 h at 20 °C. Typical colonies for each selective media were counted in plates from the dilution with 10–100 colonies.

Listeria and *Salmonella* were also researched. For these pathogens, 25 g sample was homogenized in 225 ml of primary enrichment broth (buffered peptone water) and incubated at 30 °C for 24 h. Then, 1 ml of these primary enrichments were transferred to 10 ml of *Listeria* Enrichment Broth (LEB, Merck) and incubated at 30 °C for 24 h. The enrichments were subcultured by streaking onto PALCAM *Listeria* selective agar (Merck) supplemented with PALCAM *Listeria* selective supplement (Merck) and incubated at 30 °C for 24 h. Detection of *Salmonella spp.* was carried out according to the International Standard Organization protocol (ISO 6579, 2002).

2.6. Microscopy analysis

Samples of 1 cm^3 each were immediately immersed in buffered formaldehyde solution (10% v/v), followed by dehydration in ethanol solution (15 min each) at increased concentrations (50–100% v/v). Then, immersed in ethanol:xylol solution (50:50 vol:vol) for 15 min at 4 °C, and finally included in paraffin. Transversal sections, 10 μm thick were cut using a microtome LEICA RM 2255 and allowed to air-dry. Sections were stained with hematoxilin–eosin solution. From these stained samples, muscular fiber diameters were measured in around 200 muscle fibers per sample, using an optical microscope NIKON ECLIPS 80i and equipped with a digital camera NIKON DXM 1200F. 2.2.